NASA-CR-193621

FINAL REPORT

TOWARDS DEVELOPING AN ANALYTICAL PROCEDURE OF DEFINING THE EQUATORIAL ELECTROJET FOR CORRECTING SATELLITE MAGNETIC ANOMALY DATA

(7/1/89-10/31/91)

GRANT
IN-46-CR

Grant No. NAGW-1819
1819

N95-14267
Unclas
G3/46 0028411

(NASA-CR-193621) TOWARDS DEVELOPING AN ANALYTICAL PROCEDURE OF DEFINING THE EQUATORIAL ELECTROJET FOR CORRECTING SATELLITE MAGNETIC ANOMALY DATA Final Report, 1 Jul. 1989 - 31 Oct. 1991 (Purdue Univ.) 45 p

Submitted to

National Aeronautics & Space Administration
Code EE1
NASA Headquarters
Washington, DC 20546

October, 1991

Dhananjay Ravat* & William J. Hinze
Department of Earth & Atmospheric Sciences
Purdue University, West Lafayette, IN 47907

*presently at: Department of Geology, Southern Illinois University, Carbondale, IL 62901

TOWARDS DEVELOPING AN ANALYTICAL PROCEDURE OF DEFINING THE EQUATORIAL ELECTROJET FOR CORRECTING SATELLITE MAGNETIC ANOMALY DATA

ABSTRACT

Analysis of the total magnetic intensity MAGSAT data has identified and characterized the variability of ionospheric current effects as reflected in the geomagnetic field as a function of longitude, elevation, and time (daily as well as monthly variations). This analysis has verified previous observations in POGO data and provide important boundary conditions for theoretical studies of ionospheric currents. Furthermore, the observations have led to a procedure to remove these temporal perturbations from lithospheric MAGSAT magnetic anomaly data based on 'along-the-dip-latitude' averages from dawn and dusk data sets grouped according to longitudes, time (months), and elevation. Using this method, high-resolution lithospheric magnetic anomaly maps have been prepared of the Earth over a ±50° latitude band. These maps have proven useful in the study of the structures, nature, and processes of the lithosphere.

This research has led to three manuscripts, two are in press and one is ready for submittal, two published abstracts, and one Ph.D. dissertation at Purdue University.

INTRODUCTION

This final report describes important scientific contributions made under NASA grant NAGW-1819 in identifying the effects and the variability of equatorial ionospheric current effects in MAGSAT data and the methodologies developed for isolation of the ionospheric effects and the lithospheric anomalies from the MAGSAT data. This research project has resulted in completion of one Ph.D. dissertation at Purdue University and two published abstracts. Three manuscripts have been written that are presently in the publication process (two have been accepted for publication and the other has been pre-reviewed and will be submitted for publication shortly).

The major contributions of this research are the following: 1) identification and characterization of variability of ionospheric current effects in total intensity MAGSAT data as a function of longitude, elevation, and time (daily and monthly variations), 2) development of a procedure to remove these variations from lithospheric MAGSAT magnetic anomaly data, taking into account the above variability, 3) preparation of global (±50° latitude band) high resolution lithospheric magnetic anomaly maps from the above procedure, and 4) preparation of global (±50° latitude band) apparent ionospheric magnetic anomaly maps at the two MAGSAT time-nodes, dawn and dusk. These results are documented in a manuscript that will be submitted for publication shortly (listed as Citation 1). In addition, with our analysis of along-the-dip-latitude (ATDL) MAGSAT averages, we have been able to verify two results from POGO data that had been regarded as suspect for more than a decade (personal communication, Prof. C.A. Onwumechili, London, England, September, 1991). The first result pertains to longitudinal variability in the amplitudes of the equatorial ionospheric signatures. A theoretically unanticipated peak in the equatorial ionospheric amplitudes of POGO averages was observed at 100°E longitude (Cain and Sweeney, 1973). Our results from dusk MAGSAT data suggest that the peak is present in March, but not in December (Figures 3 and 6 of Citation 1). The other suspect POGO result pertains to anomalous increase in the amplitudes of equatorial ionospheric signatures with elevation in the altitude range 450-500 km in the South American sector (Onwumechili and Agu, 1980, Onwumechili, 1985). With our dusk MAGSAT ATDL averages, we have been able to verify this anomalous increase (Figure 5b of Citation 1). These results have important bearing on theoretical models of equatorial ionospheric phenomena and the use of these models in precisely isolating lithospheric and ionospheric magnetic anomalies from the available satellite magnetic data and future magnetic satellite missions. These results are also part of Citation 1.

Citation 1:

Ravat, D.N., and W.J. Hinze, 1991, Consideration of variation in ionospheric field effects in mapping equatorial lithospheric MAGSAT anomalies, Preprint (to be submitted to The Journal of Geophysics).

Our early analyses of equatorial ionospheric signatures from Africa and South America under this project proved useful in compilation of high resolution lithospheric magnetic anomaly maps of Africa, South America, and South Atlantic. These high resolution MAGSAT magnetic anomalies were then subject to stabilized geophysical inversion and were transformed into reduced-to-pole magnetic anomalies, effective susceptibility contrasts maps, and lithospheric magnetic models by the procedures developed during our earlier NASA projects (von Frese et al., 1981; von Frese et al., 1988; Ravat et al., 1991). These early results are part of a Ph.D. dissertation conducted at Purdue University (listed as Citation 2). Comparison of the above maps and the related geologic and geophysical evidence across reconstructed margins of Africa and South America has suggested a causal relationship between the reduced-to-pole MAGSAT minima and the Mesozoic hotspot magmatism that may have partially replaced continental lower crustal rocks. These geologic inferences would not have been possible without the precise isolation of lithospheric magnetic anomalies initiated under this project. The results of the above investigation are included and cited under Citation 3.

Citation 2:

Ravat, D.N., 1989, MAGSAT investigations over the greater African region, Ph.D. Dissertation, Purdue University, 234p.

Citation 3:

Ravat, D.N., W.J. Hinze, and R.R.B. von Frese, 1991, Analysis of MAGSAT magnetic contrasts across Africa and South America, Tectonophysics, in press.

In addition, the early results on variations in equatorial ionospheric current effects in MAGSAT data were presented at the 1990 Spring meeting of the American Geophysical Union and are included here as Citation 4.

Citation 4:

Ravat, D.N., and W.J. Hinze, 1990, Variations in equatorial ionospheric effects: Their impact on mapping long-wavelength lithospheric magnetic anomalies, EOS, 71, p.485.

Furthermore, an invited paper was presented at the XXth IUGG meeting that contained results of research performed under this grant. The abstract of this paper is included here as citation 5.

Citation 5:

Hinze, W.J., and P.T. Taylor, 1991, Regional magnetic anomalies for crustal studies: Opportunities and challenges, XXth General Assembly IUGG, Vienna, Austria, 11-24 August 1991, IAGA Program and Abstracts, p. 641.

The results of this research are also included in part in a paper that is in press in *Advances in Space Research* as a result of a special session held at the 1990 COSPAR meetings in The Hague, Netherlands. This paper is referenced as Citation 6.

Citation 6:

Taylor, P.T., W.J. Hinze, and D.N. Ravat, 1991, The search for crustal resources: MAGSAT and beyond, Adv. Space Res., in press.

The entire preprint of Citation 1 is included in Appendix A. Abstracts of Citations 2, 3, 4, 5, and 6 are also included as Appendix B.

REFERENCES

Cain, J.C., and R.E. Sweeney, 1973, The POGO data, J. Atm. Terr. Phys., 35, 1231-1247.

Onwumechili, C.A., 1985, Satellite measurements of the Equatorial Electrojet, J. Geomag. Geoelectr., 37, 11-36.

Onwumechili, C.A., and C.E. Agu, 1980, General features of the magnetic field of the Equatorial Electrojet measured by POGO satellites, Planet. Space Sci., 28, 1125-1130.

Ravat, D.N., W.J. Hinze, and R.R.B. von Frese, 1991, Lithospheric magnetic property contrasts within the South American plate derived from damped least-squares inversion of satellite magnetic data, Tectonophysics, 192, 159-168.

von Frese, R.R.B., D.N. Ravat, W.J. Hinze, and C.A. McGue, 1988, Improved inversion of geopotential field anomalies for lithospheric investigations, Geophysics, 53, 375-385.

von Frese, R.R.B., W.J. Hinze, and L.W. Braile, 1981, Spherical-earth gravity and magnetic anomaly modeling by Gauss-Legendre Quadrature Integration, J.Geophys., 49, 234-242.

APPENDIX A

CONSIDERATIONS OF VARIATIONS IN IONOSPHERIC FIELD EFFECTS

IN

MAPPING EQUATORIAL LITHOSPHERIC MAGSAT MAGNETIC ANOMALIES

D. N. Ravat

Department of Geology
Southern Illinois University
Carbondale, IL 62901

and

W. J. Hinze

Department of Earth and Atmospheric Sciences
Purdue University
West Lafayette, IN 47907

ABSTRACT

For improved isolation of equatorial lithospheric MAGSAT magnetic anomalies, longitudinal, seasonal, and altitude-dependent variability of "ionospheric" averages is investigated. An estimate of the "ionospheric effect" was compiled by averaging the total intensity MAGSAT anomalies as a function of dip latitudes (called 'along-the-dip-latitude' or ATDL averages) from the dawn and the dusk data sets grouped according to longitudes, time (months), and altitudes. Consideration of longitudinal and altitude-dependent variations in the ATDL averages is important to the isolation of the equatorial lithospheric MAGSAT anomalies. Small, but unanticipated seasonal variations were found in the dusk MAGSAT data over the African-Indian sector; if the observed seasonal variations are real, they would

significantly contribute toward the theoretical understanding of the equatorial electrojet.

The amplitudes of the dawn ATDL averages are small in comparison to the dusk averages and they are of opposite sign as anticipated from the westward and eastward flowing currents at the dip equator at dawn and dusk time, respectively. However, longitudinal variation in the equatorial amplitudes of the dawn ATDL averages is not entirely consistent with present knowledge of the electrojet field. In the past, dawn MAGSAT anomalies have been considered to be free of the ionospheric fields. However, in the preparation of the lithospheric component maps, neglecting to remove the dawn ATDL averages from the dawn MAGSAT data set leaves conspicuous east-west trending anomalies in certain regions of the world. Removal of both the dawn and the dusk ATDL averages from their respective data sets substantially improves the agreement between the separately prepared dawn and dusk lithospheric component MAGSAT maps. Despite the agreement between the resultant lithospheric anomaly maps, ATDL averages do appear to contain some contribution from the lithospheric fields. Thus, processing of the data with the aid of the ATDL averages unavoidably removes a small degree of east-west oriented lithospheric signal as well.

INTRODUCTION

Significant spatial variations of the equatorial ionospheric fields have impaired the utility of equatorial MAGSAT magnetic anomalies derived for lithospheric interpretation. Early MAGSAT maps contained broad anomaly trends oriented along equatorial dip latitudes which made the interpretation of the lithospheric anomalies virtually impossible in some regions. The discovery of the anti-symmetry of Y-component from the dusk MAGSAT data (i.e., data collected at 1800 hours local time) led Maeda et al. (1982) to propose a meridional current system in the equatorial ionosphere. Their continued studies showed the altitude-dependent and longitudinal variability of this effect (inversely proportional to altitude and equatorial field strength) (Maeda et al., 1982, 1985). No corresponding variations in the dawn Y-component MAGSAT data (600 hours local time) are observed. Later, Yanagisawa and Kono (1984, 1985) observed unusual variations in X- and Z-components near the dip equator in both dawn and dusk MAGSAT subsets. Amplitudes of these variations are relatively small and can be isolated only if data are averaged along dip latitudes to reduce the lithospheric component. The averaged Z-component variations are anti-symmetric about the dip equator and opposite between dawn and dusk, whereas, the X-component variations are more or less symmetric about the dip equator and opposite between dawn and dusk. The amplitudes of the dawn variations are generally significantly smaller than the dusk variations. Yanagisawa and Kono (1984, 1985) removed these 'mean ionospheric field' averages to obtain 5°X5° lithospheric component maps. The inherent assumption of the correction is that lithospheric anomaly contribution to the mean ionospheric field averages is negligible.

Cohen and Achache (1990) questioned the validity of the assumption made by Yanagisawa and Kono (1984, 1985). Instead, they assume that commonalities between the dawn and the dusk averages obtained as a function of dip latitudes (in this paper, called 'along-the-dip-latitude' or ATDL averages) are due to lithospheric component and differences between the averages are due to the differences in the ionospheric fields at the two observation times. They use half of the difference between the dawn and the dusk averages (considered by them to be the electrojet effect) to derive the individual lithospheric components after scaling the 'electrojet effect' to the individual MAGSAT profiles. The 'electrojet effect', in their study, was derived separately for each component and for four sectors of the world (to represent the longitudinal variability), whereas, scaling the effect to individual passes accounts for time and altitude variations. Although it is clear that the differences in the dawn and dusk ATDL averages are caused by the differences in the ionospheric fields at the two local times, it is important to note that these differences do not represent ionospheric field signatures at either of the two MAGSAT time nodes (unless the ionospheric field at one of these time nodes was negligible). Hence, the correction process implemented by Cohen and Achache essentially reduces the differences between the dawn and the dusk observations by fitting a scaled average position in between the respective ATDL averages.

An alternative approach to the problem is to examine the individual dawn and dusk ATDL averages. This is a more useful technique for exploring the equatorial ionospheric variations (and not their differences) - even at the risk of including some lithospheric component by the averaging process. In addition, it seems likely that some of the dawn ionospheric fields may appear morphologically similar to the dusk ionospheric fields. Thus, some of the commonalities between the dawn and the dusk ATDL averages may indeed be of ionospheric origin.

Langel et al. (1991) extracted a substantial amount of information about the characteristics and morphology of the dusk-side equatorial electrojet fields. They approximated the individual magnetic components by fitting a function inversely dependent on the height of the electrojet and the magnitude of the geomagnetic field (as previously substantiated by Maeda et al. (1982, 1985) from the MAGSAT observations and by Cain and Sweeney (1973) from the POGO observations). Then, they computed vertical current density from the horizontal components and east-west currents and density from the anomalous X- and Z- components. In addition, they showed that use of the field models prior to GSFC 12/83 systematically enlarge amplitudes of the dawn ATDL averages because these field models were contaminated by the meridional currents which strongly affect the dusk-side Y-component observations (Maeda et al., 1982).

We have previously used the approach of Yanagisawa and Kono (1984, 1985) in connection with isolating the total intensity lithospheric component data over Africa and South America at the average MAGSAT altitude (~400 km). However, instead of computing the ATDL averages from the individual components, we computed the ATDL averages directly from the total intensity anomalies. Also, the averages were computed for each 1° of dip latitude, over an ~90° longitudinal swath, and by excluding the prominent lithospheric Bangui Anomaly region (Regan et al., 1975). The averages were then subtracted from the respective dawn and dusk data sets only in a dip latitude range of about ±20° of the dip equator (i.e., only in a region where the east-west banding is prominent). Without the removal of both the dawn and the dusk ATDL averages from the respective data sets, strong east-west bands of dawn-dusk discrepancies were present over the African region (Ravat, 1989). Both dawn and dusk ATDL averages showed prominent amplitudes over Africa, but only the dusk ATDL averages were prominent in South America (see, e.g., lower panels in Figures 1 and 2). In the light of the findings by Langel et al. (1991), it is worthwhile mentioning that the GSFC 12/83 geomagnetic field model (Langel and Estes, 1985) was used in our studies.

The purpose of this study is to investigate nature of the variations of the total intensity ATDL averages in the equatorial region so that isolation of the lithospheric component could be improved. We, therefore, investigate the longitudinal, seasonal, and altitude-dependent variability of the equatorial excursions of the dawn and the dusk ATDL averages. Because POGO satellites measured scalar magnetic field, a direct comparison between the POGO results (Cain and Sweeney, 1973; Onwumechili, 1985) and the results of the total intensity MAGSAT ATDL averages is possible. Compatibility of MAGSAT and POGO results would indicate that the MAGSAT ATDL averages are closely approximating the ionospheric fields because the day-time equatorial POGO variations are significantly larger, and less ambiguous, than the twilight MAGSAT variations. Our approach is empirical, but we aim to analyze the advantages and the drawbacks of the procedure used rather than presenting a definitive processing scheme for extracting either pure ionospheric or pure lithospheric components. Theoretical and experimental models and observations of the equatorial ionospheric fields are not considered here; their up-to-date description can be found in the reviews by Onwumechili (1967, 1985), Cain and Sweeney (1973), Forbes (1981), Maeda et al. (1982, 1985), Rastogi (1989), and Kelly (1989).

ANALYSIS OF THE ALONG-THE-DIP-LATITUDE (ATDL) AVERAGES

The purpose of the analysis of the individual dawn and dusk ATDL averages computed and grouped according to longitudes, months, and altitudes is to observe systematic patterns in the near equatorial variations. If the variations are systematic, a much improved correction is feasible for isolating the lithospheric anomalies.

Initial Data Processing. Preliminary data processing involved the removal of both the geomagnetic field computed from the GSFC 12/83 field model (Langel and Estes, 1985) and the effect of the ring current (Langel and Sweeney, 1971) and then computation of the total intensity anomalies from the orthogonal components. Each MAGSAT profile was then visually examined for spurious activity; only profiles having nearly continuous signals were retained after despiking. The long-wavelength residuals of the ring current correction and very short-wavelength noise were then minimized with a 5°-40° bandpass filter (similar to Ridgway and Hinze, 1986). The profiles were then grouped according to months (November to April) and altitude ranges (300-350, 350-400, 400-450, 450-500, 500-550 km) separately for the dawn and the dusk data sets. The ATDL averages and their standard deviations were compiled at every 45° of longitude for each of the above groups. For every individual ATDL average profile, the averaging was performed over a 90° longitudinal swath (excluding the region of the prominent lithospheric Bangui Anomaly). Eight ATDL averaged profiles were obtained in this manner, each separated by 45° from the neighboring ones, from each of the above groups. Generally, each average is compiled from 80 to 100 data points. The averaged curves are relatively smooth and their standard deviations are nearly uniform for individual ATDL profiles within a dip latitude band of ±30°, and therefore, it appears that sufficient averaging has been achieved to extract common phenomena parallel to dip latitudes.

Morphology of the ATDL Averages. At the dip equator, the dusk ATDL averages show prominent negative total intensity anomaly that is nearly always centered at the dip equator (e.g., see Figures 1 and 2). The negative anomaly is flanked by unequal positive side-lobes which extend out to about ±15°-20° dip latitudes. This signature is present in the dusk ATDL averages for all longitudes and elevations. The dusk ATDL signature is similar to the signature observed from the POGO data (Cain and Sweeney, 1973; Onwumechili, 1985) and other MAGSAT investigations (e.g., Maeda et al., 1985; Yanagisawa and Kono, 1985; Langel et al., 1991) and is characteristic of eastward-flowing equatorial currents. On the other hand, the dawn ATDL averages show a very small positive total intensity anomaly centered at the dip equator. The dawn signature is negligible to absent in the Eastern Pacific and South American sectors. The positive dawn signature appears to be consistent with the small intensity westward flowing current at the dip equator.

Longitudinal Variations. Confirmation that the dusk ATDL averages at the dip equator represent ionospheric phenomenon is obtained by comparing the longitudinal variation of the dusk MAGSAT averages to that of the day-time POGO averages from Cain and Sweeney (1973). As mentioned previously, the day-time POGO variations are much higher in amplitude because of the enhanced day-time ionospheric conductivity at the dip equator; thus, the ambiguity in establishing the longitudinal variation from the POGO amplitudes is minimal. Comparison of the longitudinal variation in the amplitudes of POGO and dusk MAGSAT equatorial amplitudes (normalized to POGO) show that they vary similarly (Figure 3). Both the POGO and the dusk MAGSAT averages show a large amplitude peak near 75°-90°W and a smaller peak near 90°-100°E. The higher peak in the western hemisphere is consistent with theoretical and experimental considerations of ionospheric conductivities, where existing theories based on the magnitude of the ambient geomagnetic field intensity predict a maximum. The secondary peak at 100°E is considered to be associated with the prevailing winds in that region (Cain and Sweeney, 1973; Onwumechili, 1985). On Figure 3, the amplitudes of the equatorial positive anomaly from the dawn ATDL averages are also shown (four times exaggerated). Their variation is nearly opposite to those of POGO and dusk MAGSAT variations. We are unaware of any theories that predict this variation. We note, however, that the amplitudes of these disturbances in the Western Pacific are fairly high in the lower altitude data (~1.5-2 nT) and, thus, consideration of these variations may be important in the preparation of the lithospheric component maps.

In addition to the above equatorial dawn variations, the dawn ATDL averages contain other appreciable variations south of the dip equator in a longitudinal swath from Africa to Western Pacific. The expression of this variation is readily apparent in the lower panels of Figure 1 in the form of a prominent negative excursion at about -7° dip latitude. If corrections to the dawn data were not applied to eliminate this effect, the dawn and the dusk lithospheric magnetic anomalies would not be compatible as is necessary for the stationary lithospheric magnetic anomaly signal. To demonstrate this point, we have computed the dawn and the dusk 2° averaged MAGSAT anomalies from the data between 300 and 400 km elevation. In the case of the dusk anomalies, the ionospheric effects were removed by subtracting the dusk ATDL averages at 350 km elevation between ±25° dip latitude. Based on the characteristic nature of the dusk ATDL averages and the consistency of the dusk ATDL averages and the POGO averages, the resulting dusk data may be considered relatively free from the ionospheric effects. No corrections were applied to the dawn anomalies. The resulting dawn-dusk difference map shows prominent difference bands mainly from Africa to Western Pacific (shown by arrows on Figure 4). If both the dawn and the dusk data sets were of purely lithospheric origin, such differences should not be present. In addition to the banding near -7° to -10° dip latitude, the dawn-dusk anomaly discrepancies are also high at the dip equator in Africa and Western Pacific (these are the regions where the peaks of the dawn curve in Figure 3 were observed). Thus, unless the dusk ATDL averages do not approximate the ionospheric effects at the dip equator - and there is no reason to believe that based on the compatibility of the MAGSAT dusk and the POGO averages, it appears that corrections to the dawn anomalies are also necessary in some regions of the world.

In spite of the above arguments, the origin of the strong dawn variations away from the dip equator (i.e., at -7° of dip latitude) are problematic as an ionospheric phenomena. Despite the uncertainty in the origin of these variations, it seems extremely unlikely that they are lithospheric. Thus, regardless of their origin, it appears reasonable to remove the banding caused by these variations when preparing lithospheric magnetic anomaly maps.

Altitude Variations. Next, we investigate the amplitude variations of the ATDL averages with altitude to determine whether the variations could be approximated by simple amplitude-elevation attenuation functions, globally. We found that although the amplitudes of the ATDL averages attenuate with altitude in general (e.g., Figures 1 and 2), the variation with altitude is not systematic throughout the earth, and other spurious effects are present (Figure 5). Thus, the ATDL averages cannot be fitted to individual passes by predetermined amplitude-elevation attenuation functions in correcting the MAGSAT data for lithospheric analysis.

With regard to the above investigation of the amplitudes of the ATDL averages at different elevations, it is worthwhile to note an interesting side-issue. In the South American sector, the dusk amplitudes increase between the altitudes of 425 and 525 km (Figure 5). A similar increase of amplitudes in the same elevation range has also been observed by Onwumechili and Agu (1980) from the South American day-time POGO data. Thus, the observed amplitude variability with altitude may be real and not the artifact of singular points (such as 475 km elevation point in the South American dusk data). The compatibility of the POGO and dusk MAGSAT averages suggest that other less prominent ionospheric sources (or sinks) may be present at high altitudes and can affect the observations.

Monthly Variations. The seasonal variability in the position of the equatorial excursion appears to be present only in the African-Indian sector and only for the dusk ATDL averages. In the African sector, from the dusk MAGSAT data, there appears to be a seasonal movement in the position of the dusk trough from a few degrees south of the dip equator in November-December to the dip equator in January-April. How reliable the ATDL averages showing this phenomenon are (not shown here, Ravat and Hinze, 1990) and what their significance is in terms of ionospheric dynamics are difficult to judge. The POGO data may be helpful in verifying such results. Another type of seasonal variation appears to be significant for the theoretical models that predict inversely proportional ionospheric conductivity to the magnitude of the geomagnetic field intensity. For the time-averaged POGO and dusk MAGSAT data, two peaks in the equatorial ionospheric amplitudes can be observed across the earth (when theory predicts only one) (see Figure 3). The comparison of the longitudinal variability in the amplitudes of the December and March dusk ATDL averages shows that for the December dusk ATDL averages the peak at 100°E longitude is absent (Figure 6). The dusk ATDL averages for the month of December are nearly inversely proportional to the field intensity as predicted by theory (Sugiura and Cain, 1966; Sugiura and Poros, 1969).

Ingredients of a Correction Procedure. Based on the above analyses of the dawn and the dusk variations of the ATDL averages, the following deductions are made and should be useful for an improved elimination of non-lithospheric components from the lithospheric total intensity MAGSAT anomalies: 1) The ATDL averages are more meaningful in terms of ionospheric effects (Yanagisawa and Kono, 1984) than the difference between the dawn and the dusk ATDL averages (Cohen and Achache, 1990). This conclusion is made because the dusk ATDL variations favorably compare with the variability of the day-time POGO averages and theoretical predictions; the dawn ATDL averages are derived by the same procedure, although they are weak in amplitude. 2) The equatorial dawn MAGSAT anomalies must be corrected as well as the dusk because neglecting to correct dawn variations produces spurious bands of dawn-dusk discrepancies (Figure 4). 3) The longitudinal variations in the ATDL averages is significant and, therefore, the ATDL averages should be computed at a finer longitudinal interval than has been used heretofore. 4) The shape of the ATDL averages is similar at all MAGSAT elevations and although the amplitudes vary with elevation, there is no systematic amplitude attenuation with elevation. Therefore, least-squares fitting (Cohen and Achache, 1990) of the ATDL averages (but not the differences) to the individual MAGSAT profiles is necessary. 5) The cause of the seasonal variability in the dusk ATDL averages in the African-Indian sector is not well-understood and needs independent verification. Therefore, the variability may not be taken into account in reducing the lithospheric MAGSAT anomalies at this time.

After consideration of the above conclusions, a correction that incorporates scaling the ATDL averages to individual MAGSAT profiles seems most appropriate, i.e., a hybrid process between those of Yanagisawa and Kono (1984) and Cohen and Achache (1990). Scaling the ATDL averages will be necessary to avoid anomaly artifacts created by applying the simple average-altitude ATDL correction to high and low altitude profiles. Implementation of such a correction is discussed in the next section along with the analysis of its advantages and drawbacks.

THE IMPLEMENTATION AND ANALYSIS OF THE IMPROVED ATDL CORRECTION

Analysis of performance of corrections to MAGSAT data for improving the lithospheric anomalies requires a careful examination of dawn-dusk discrepancies at individual data point locations as well as an examination of overall statistical parameters before and after the correction. Accordingly, magnetic anomalies at the dawn and the dusk profile cross-over locations were computed. Because the lithospheric signal is stationary at both the observation times, we may assume that the magnetic anomaly differences at the dawn-dusk cross-over locations originate from the differences in ionospheric fields at the two observation times and the differences in altitudes of the two observations. Minimization of these differences is the aim of the corrections.

The dawn and the dusk 90° ATDL averages were computed at the average MAGSAT altitude at 1° longitudinal spacing to express the longitudinal variability. Once again, the lithospheric Bangui Anomaly region was excluded from the averaging process to reduce the lithospheric bias. A simple least-squares scaling of the ATDL averages to the individual MAGSAT profiles was found to be too sensitive to the nature and magnitude of the lithospheric anomalies. This procedure resulted in spurious overcorrections in regions where high-amplitude lithospheric anomalies are in-phase with the ATDL averages, suggesting that a more elaborate procedure was necessary.

Appropriate scaling of the ATDL averages to the individual profiles was achieved by a simultaneous inversion for the scaling parameters for all the passes within each of the four (overlapping) sectors of the earth and with a constraint that the scale factors minimize the dawn-dusk discrepancies at the cross-over locations. The method is similar to one proposed by Ray (1985) for minimization of aeromagnetic tie-location discrepancies. Ray's method has been successfully used for minimization of long-wavelength dawn-dusk discrepancies over eastern Europe (Ravat, 1989). In the present implementation, coefficients were computed to scale the ATDL averages that minimize the dawn-dusk discrepancies between ±25° dip latitude. The ATDL averages scaled to the individual profiles were then removed from the respective dawn and the dusk data sets. The improved dawn and dusk MAGSAT maps (Figures 7a and 7b) altitude-normalized to 400 km elevation by least-squares collocation (Goyal et al., 1990) show that these maps are highly correlated at the regional scale of this study. The comparison of the dawn-dusk cross-over discrepancies before the correction (from 2° averaged maps) and after the correction (from collocated maps) shows marked improvement as a result of the correction (Figures 8a and 8b). No equatorial dip latitude oriented discrepancies are observed in Figure 8b.

On a regional scale, the comparison of the dawn-dusk discrepancies before the correction, after the simple average-altitude ATDL correction (similar to Yanagisawa and Kono, 1984), and after the modified scaled ATDL correction shows the overall improvement in the statistical parameters due to the corrections (Figures 9a, 9b, and 9c). The improvement in the scaled ATDL correction over that of the simple ATDL correction is due to consideration of representing the longitudinal variability and the variation in amplitudes of the ATDL averages in individual profiles at various altitudes. As suggested before, the simple ATDL correction is derived at the average MAGSAT altitude and, consequently, undercorrects the high activity - generally lower altitude - MAGSAT passes and overcorrects the low activity - generally high altitude - MAGSAT passes.

On a local scale, the performance of the corrections may only be made after a close scrutiny of the dawn and the dusk anomalies at their cross-over locations. To investigate the utility of the corrections, we have closely examined 50 dawn and dusk profiles. An overwhelming number of these profiles showed significant improvement due to the modified scaled ATDL correction over that of the simple average-altitude ATDL correction (92%), although examples of failure of both of these methods can be found as well (6%). In Figure 10, we show examples of improved as well as deteoriorated dawn-dusk discrepancies along three dawn and dusk profiles. For a quick recognition of the relative changes in dawn-dusk discrepancies due to both the methods, the absolute mis-ties are shown shaded in these figures; the numerical values of the average absolute mis-tie between $\pm 25°$ dip latitude are also shown. The jaggedness of the anomaly profiles in these figures reflects the error in the data as well as the elevation differences between the dawn and the dusk profiles at the cross-over locations. The example in Figure 10a shows the improvement due to both the ATDL corrections (62% of the examined profiles), whereas, the example in Figures 10b shows that the application of the simple average-altitude ATDL correction has deteoriorated the mis-ties (30% of the examined profiles). On the other hand, the examples in Figure 10c show that in some cases neither of the corrections have succeeded their purpose (6% of the examined profiles). In one case out of 50, the simple average-altitude ATDL correction faired better than the modified scaled ATDL correction.

The magnitude of the corrections to the individual dawn and dusk profiles are useful in obtaining the global-scale snap-shots of the ionospheric effect at the dawn and the dusk local-times (Figure 11). These snap-shots are useful in determining the morphologies, nature, and relative amplitudes of equatorial ionospheric variations across the globe at the two local-times. These plots also serve to identify regions where the lithospheric anomaly leakage into the ATDL averages is likely to be large.

Possible magnetic anomaly leakage of lithospheric origin in Figure 11 can be identified only if assumptions can be made about the nature of the ionospheric fields. We assume that the ionospheric magnetic anomaly amplitudes may not be large farther away from the dip equator in comparison to their amplitudes near the dip equator. Where this condition occurs in the dusk data (Figure 11b) (because the dusk variations at the dip equator are consistent with day-time POGO data and theoretical considerations) and where an identical trend occurs in the dawn data, we may consider that trend a suspect. Based on above assumption, we have identified the most likely anomaly trends (or bands) of lithospheric origin (shown by arrows in Figure 11); these anomaly bands are suspect and should not be considered in the inferences about the nature and morphology of the ionospheric fields.

The snap-shots of the equatorial ionospheric field anomalies (Figure 11) show that: 1) the intensity of these fields at dawn is much smaller than at dusk, 2) the dusk anomalies show negative excursions at the dip equator with positive side-lobes, 3) the dusk anomalies are strongest in the South American region and weakest in the Western Pacific, 4) the positive dawn anomaly at the dip equator with negative side-lobes is strong only in the Western Pacific (i.e., an opposite behavior to dusk), 5) for dawn data, from Africa to the westernmost Pacific, the strongest ionospheric signature consists of the negative anomaly near -7° to -10° dip latitude and its weak side-lobes, and 5) at dawn, the eastern Pacific and South American regions are virtually free of ionospheric effects (as observed at 300-550 km altitude). In the case of dusk data, the ionospheric variations (Figure 11b) are in agreement with the theoretical and experimental results previously documented from the POGO and vector MAGSAT data (Cain and Sweeney, 1973; Forbes, 1981, Maeda et al., 1982, 1985; Onwumechili, 1985; Langel et al., 1991). The dawn ionospheric variations (Figure 11a), on the other hand, cannot be entirely reconciled with the expected theoretical signatures. Limited coverage of equatorial ground observatories is probably inadequate to suggest an origin of the dawn variations on Figure 11a. Langel et al. (1991) suggest that similar variations can be caused by defective data preprocessing and may not be significant from the ionospheric viewpoint -although they must be removed for the analysis of the lithospheric anomalies. Perhaps reexamination of low-altitude POGO data around 600 and 1800 hours local-times may resolve some of these issues.

The above scrutiny of the "ionospheric effects" derived from the ATDL averages suggests that the averages probably contain a varying degree of lithospheric signal; the lithospheric contamination is more apparent in regions farther away from the dip equator. However, it is difficult to isolate the lithospheric signal from the ionospheric signal from the ATDL averages without *a priori* assumptions about the individual fields. Thus, at present, it is important to apply the ATDL corrections, but recognize the inherent limitations of the corrections.

DISCUSSION AND CONCLUSION

The study of longitudinal, seasonal, and altitude-dependent variability of the dawn and dusk along-the-dip-latitude (ATDL) averages of the total intensity MAGSAT data suggests that, for the purpose of improving the equatorial lithospheric MAGSAT anomalies, consideration of the longitudinal and the altitude-dependent variability of the ATDL averages is critical. The study also shows why analytical methods of approximating the ionospheric effects in individual MAGSAT passes are difficult to devise (for example, methods such as simple potential functions describing the above variability of the ATDL averages). One reason for this difficulty is that the longitudinal variability of the equatorial amplitudes of the ATDL averages displays both short-period (changes in day-to-day strength) and long-term (possibly due to the position of the Sun) variations. The seasonal variations (e.g., March/December in Figure 6) observed in the dusk MAGSAT data over the Indian sector would be important to the electrojet models that consider as one of their parameters the magnitude of the geomagnetic field strength at the dip equator. We are not aware of experimental results that might argue for or against the validity of the MAGSAT observations. Examination of POGO data grouped according to months may prove fruitful for the verification of the MAGSAT results.

Another difficulty in analytically expressing the magnetic effect of the equatorial ionospheric fields is the possible presence of other less dominant ionospheric currents within the range of MAGSAT observation altitudes. Although these sources are small in strength in comparison to the electrojet itself, they are closer to the sensor. As a result, there is no systematic amplitude attenuation with elevation as the sensor altitude increases. We were able to confirm one such anomalous peak in the MAGSAT amplitude-elevation curves with the POGO results from the existing literature. However, detailed pass-by-pass comparisons will be necessary to completely verify and map these sources.

Based on these and other considerations, we have implemented a procedure for reducing the equatorial ionospheric effects from the lithospheric component MAGSAT data. In this procedure, the longitudinal variability of the ATDL averages is considered by finely sampling the ATDL averages (at 1° spacing, but 5°-10° longitudinal sampling should be sufficient for most purposes). The altitude-dependent variations in the amplitudes of the averages were accounted for by simultaneous least-squares scaling of the mean ATDL averages, with a constraint that the scaling parameters reduce the dawn-dusk cross-over discrepancies. This procedure led to substantial improvements in the dawn-dusk discrepancies of the lithospheric component MAGSAT data.

There are a few drawbacks in using the ATDL averages (or similar methods) for approximating the ionospheric effects. One drawback of the method is the difficulty in precisely specifying the swath of dip latitudes in which corrections must be applied. Our results suggest that farther away from the dip equator, the ATDL averages contain components of east-west trending lithospheric anomalies, but no clear and single cut-off dip latitude is indicated. A second drawback of the correction procedure utilized in the study is that the computation of the scaling parameters that fit the respective mean ATDL averages to individual passes is computer intensive and may not be suitable for all investigators of global satellite magnetic data.

REFERENCES

Cain, J.C. and R.E. Sweeney, 1973, The POGO Data, J. Atm. Terr. Phys., 35, 1231-1247.

Cohen, Y. and J. Achache, 1990, New Global Vector Magnetic Anomaly Maps Derived from MAGSAT Data, J. Geophys. Res., 95, 10783-10800.

Forbes, J.M., 1981, The Equatorial Electrojet, Rev. Geophys. Space Phys., 19, 469-504.

Goyal, H.K., R.R.B. von Frese, W.J. Hinze, D.N. Ravat, 1990, Statistical Prediction of Satellite Magnetic Anomalies, Geophys. J. Int., 102, 101-111.

Kelly, M.C., 1989, The Earth's Ionosphere, Academic Press, 487p.

Langel, R.A., M. Rajaram, and M. Purucker, 1991, The Equatorial Electrojet and Associated Currents as Seen in MAGSAT Data, submitted to J. Atm. Terr. Phys.

Langel, R.A. and R.H. Estes, 1985, The Near-earth Magnetic Field at 1980 Determined from MAGSAT data, J. Geophys. Res., 90, 2495-2509.

Langel, R.A. and R.A. Sweeney, 1971, Asymmetric Ring Current at Twilight Local Time, J. Geophys. Res., 76, 4420-4427.

Maeda, H., T. Kamei, T. Iyemori, and T. Araki, 1985, Geomagnetic perturbations at low latitudes observed by MAGSAT, J. Geophys. Res., 90, 2481-2486.

Maeda, H., T. Iyemori, T. Araki, and T. Kamei, 1982, New Evidence of a Meridional Current System in the Equatorial Ionosphere, Geophys. Res. Lett., 9, 337-340.

Onwumechili, C.A., 1985, Satellite Measurements of the Equatorial Electrojet, J. Geomag. Geoelectr., 37, 11-36.

Onwumechili, A., 1967, Geomagnetic Variations in the Equatorial Zone, *in* S. Matsushita and W.H. Campbell (eds.), Physics of Geomagnetic Phenomena, Academic Press, New York, pp. 425-507.

Onwumechili, C.A. and C.E. Agu, 1980, General Features of the Magnetic Field of the Equatorial Electrojet Measured by POGO Satellites, Planet. Space Sci., 28, 1125-1130.

Rastogi, R.G., 1989, The Equatorial Electrojet: Magnetic and Ionospheric Effects, *in* Jacobs (ed.), Geomagnetism, Volume 3, Academic Press, pp. 461-525.

Ravat, D.N., 1989, MAGSAT Investigations over the Greater African Region, Ph.D. Dissertation, Purdue University, West Lafayette, IN, 234p.

Ravat, D.N. and W.J. Hinze, 1990, Variations in Equatorial Ionospheric Effects: Their Impact on Mapping Long-Wavelength Lithospheric Magnetic Anomalies, EOS, 71, p. 485.

Ray, R.D., 1985, Correction of Systematic Error in Magnetic Surveys: An Application of Ridge Regression and Sparse Matrix Theory, Geophysics, 50, 1721-1731.

Regan, R.D., J.C. Cain, and W.M. Davis, 1975, A Global Magnetic Anomaly Map, J. Geophys. Res., 80, 794-802.

Ridgway, J.R. and W.J. Hinze, 1986, MAGSAT Scalar Anomaly Map of South America, Geophysics, 51, 1472-1479.

Sugiura, M. and D.J. Poros, 1969, An Improved Model Equatorial Electrojet with a Meridional Current System, J. Geophys. Res., 74, 4025-4035.

Sugiura, M. and J.C. Cain, 1966, A Model Equatorial Electrojet, J. Geophys. Res., 71, 1869-1877.

Yanagisawa, M. and M. Kono, 1985, Mean Ionospheric Field Correction for MAGSAT Data, J. Geophys. Res., 90, 2527-2536.

Yanagisawa, M. and M. Kono, 1984, Magnetic Anomaly Maps Obtained by Means of the Mean Ionospheric Field Correction, J. Geomag. Geoelectr., 36, 417-441.

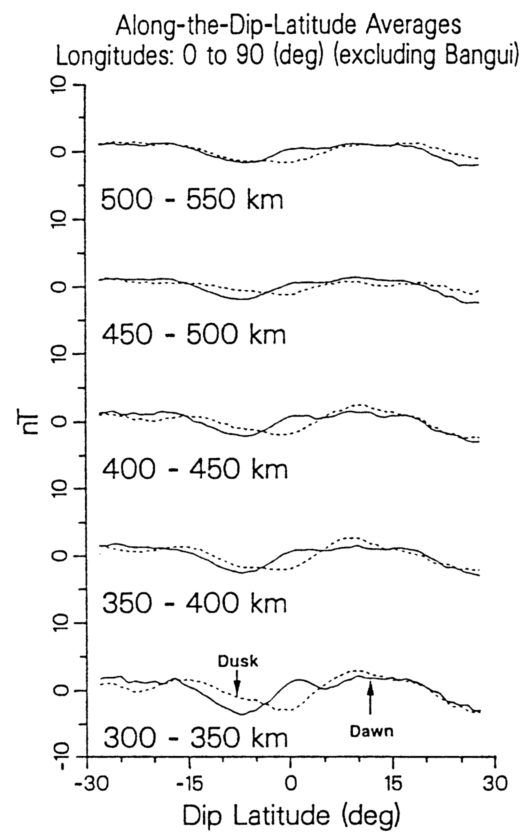

Figure 1. The dawn and the dusk along-the-dip-latitude (ATDL) averages over Africa showing some of the key features of the ATDL averages. First, the equatorial amplitudes are nearly insignificant at high altitudes in most parts of the world, but they are significant at low altitudes. Second, the dusk signature consists of a negative anomaly at the dip equator. Third, the dawn signature is a small positive anomaly at the dip equator which is embedded in an anomaly trough at -7° dip latitude. The trough in the dawn data is prominent from Africa to Western Pacific (going eastward). Dawn averages- continuous line, dusk avearages- dashed line.

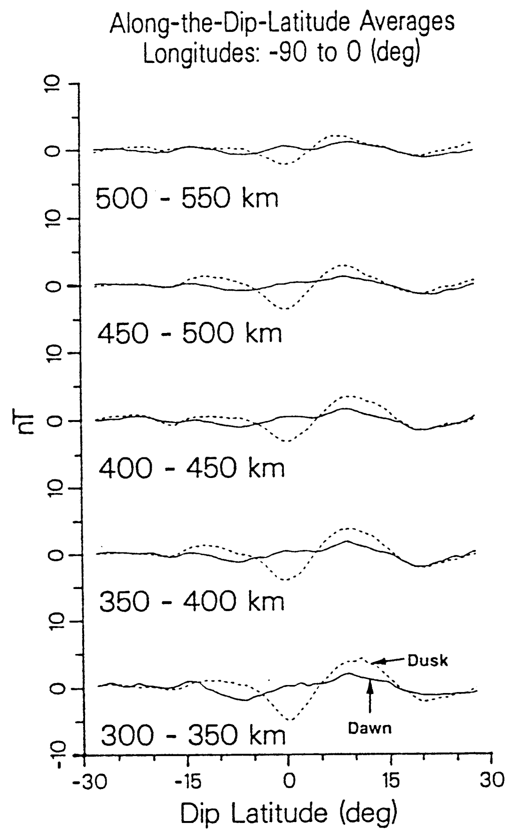

Figure 2. The dawn and the dusk ATDL averages over eastern South America at various altitudes.

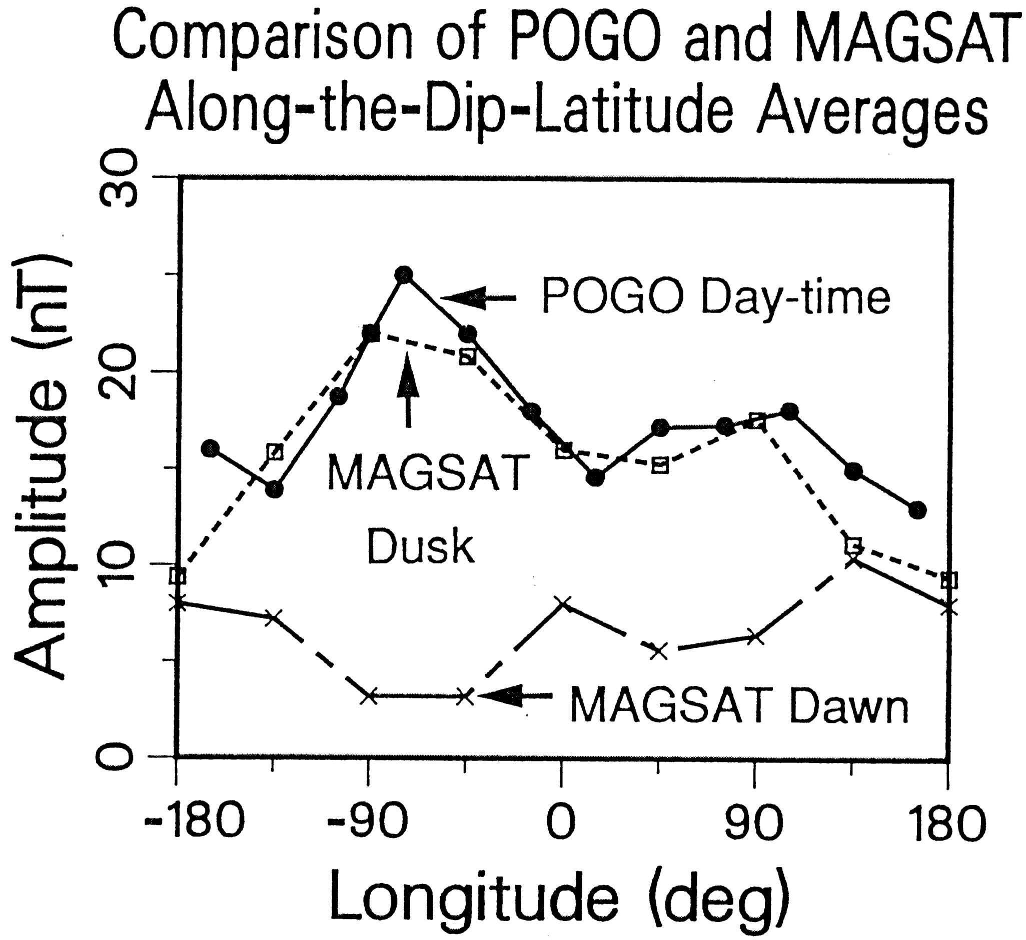

Figure 3. Amplitude variation of the equatorial ATDL average anomalies with respect to longitudes. POGO amplitudes are from Cain and Sweeney (1973). MAGSAT dusk amplitudes are normalized to POGO amplitudes at -90° longitude. The dawn MAGSAT curve is exaggerated four times its own values.

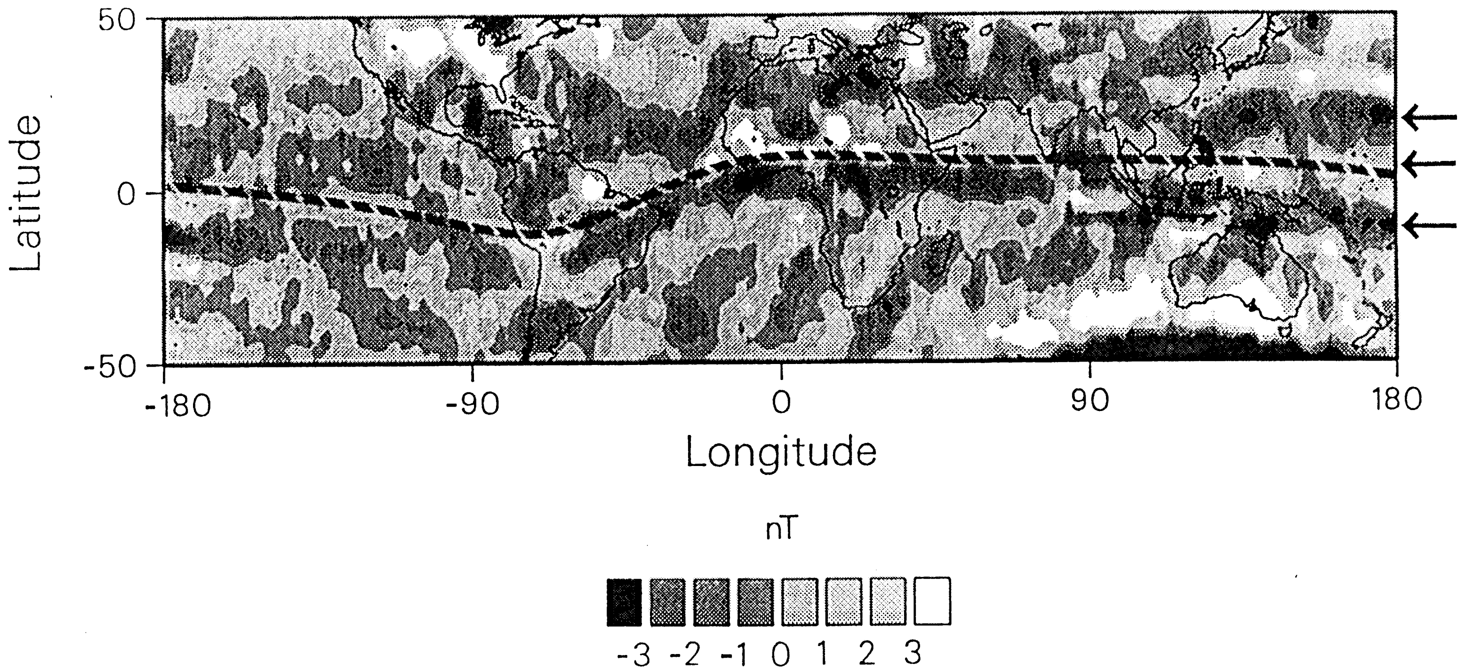

Figure 4. Nature of the dawn-dusk anomaly discrepancies, if it is assumed that only the dusk data contains significant ionospheric effects. Shade interval 1 nT. The heavy dashed line marks the dip equator. Under this assumption, large discrepancies occur near the dip equator from Africa to Western Pacific (shown by arrows). Discrepancy bands south of Australia are related to the auroral oval and are not considered in this study.

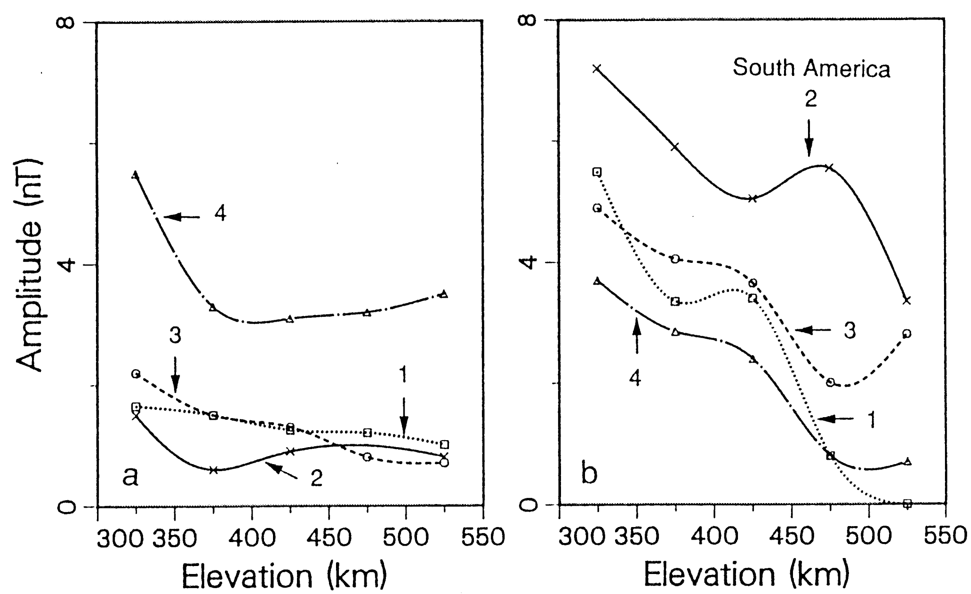

Figure 5. Examples of variations in amplitudes of the equatorial ATDL average anomalies with elevation. a) dawn ATDL averages, b) dusk ATDL averages. The ATDL averages are compiled from averaging the data in 50 km elevation range and 90° longitudinal swath; they are shown at the center of their respective range. 1- 135°W, 2- 45°W, 3- 45°E (excluding Bangui), and 4- 135°E.

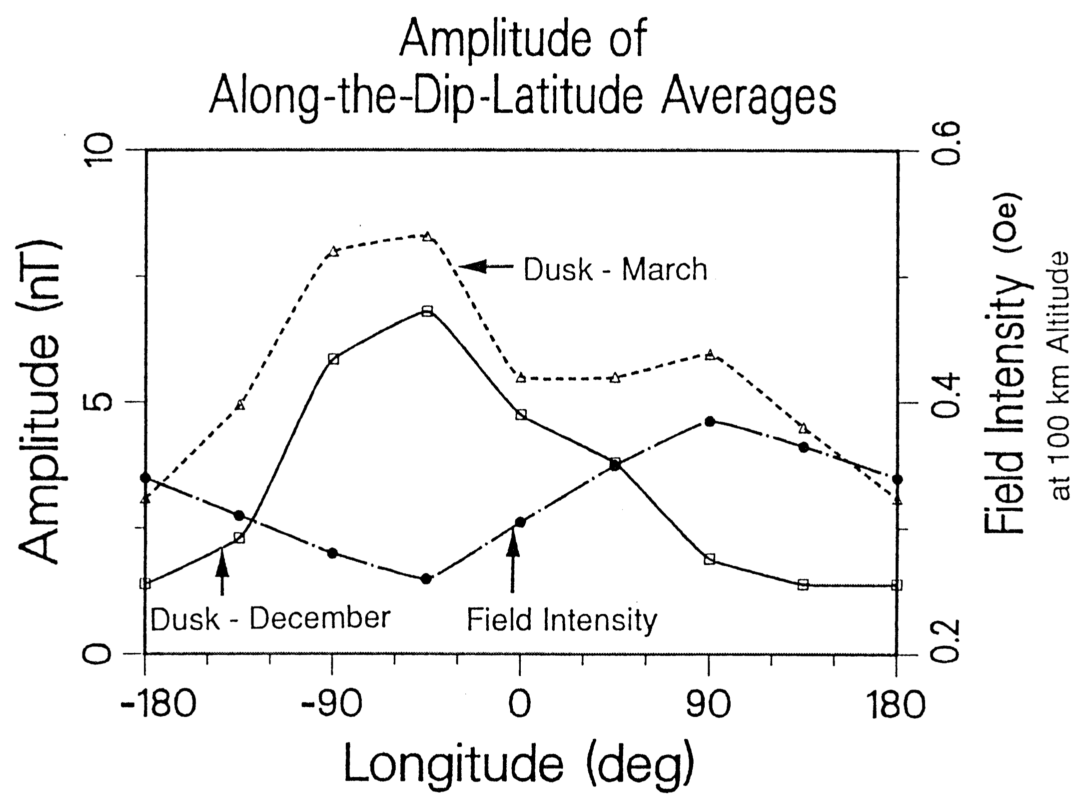

Figure 6. A possible seasonal variation of theoretical importance may be present at 90°E-100°E longitude. Regarding this possibility, see text for details. In general, March amplitudes are larger than December amplitudes because the average satellite altitude was lower in March than in December.

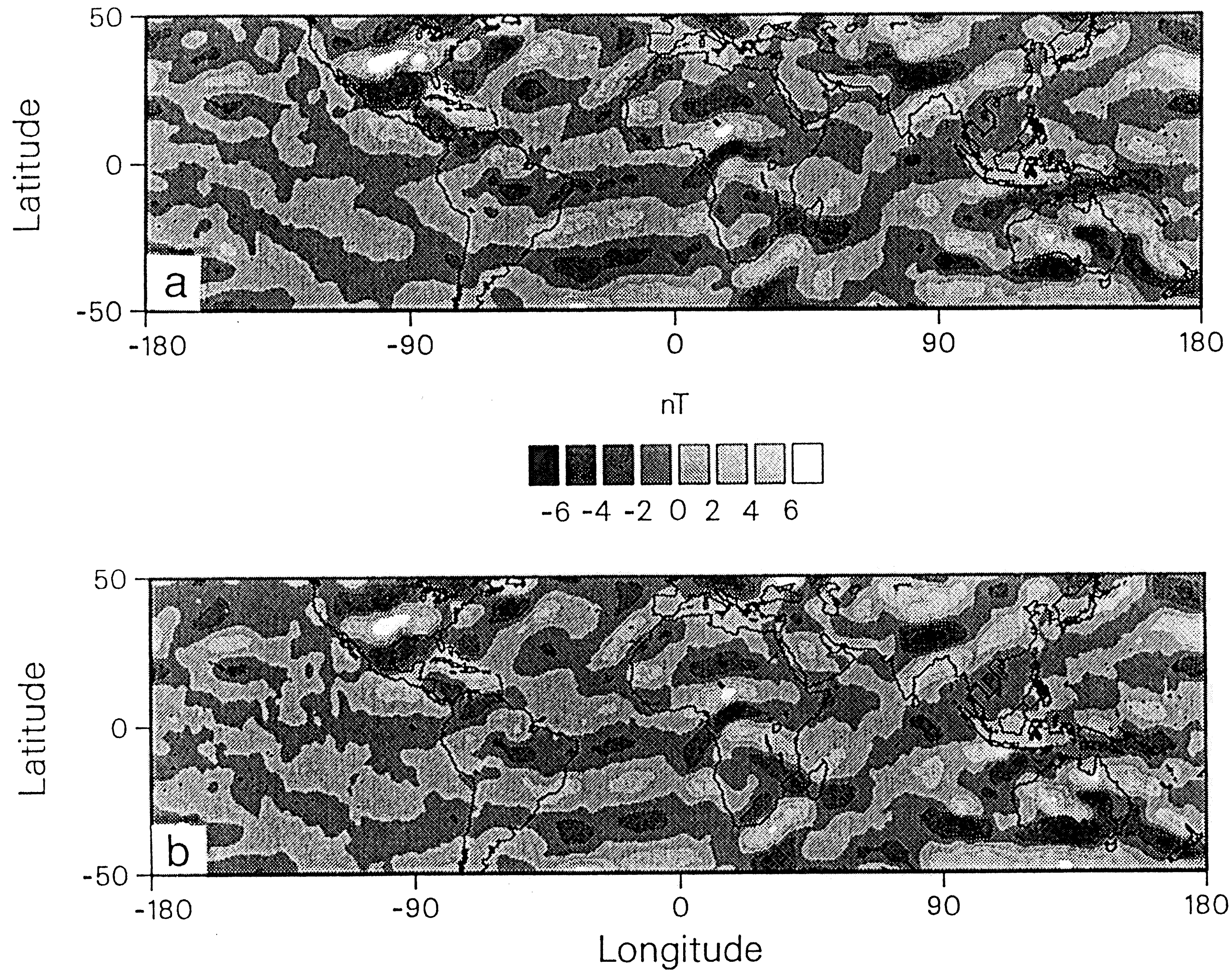

Figure 7. Improved lithospheric total intensity magnetic anomaly maps prepared by the processing used in this study. a) dawn anomalies and b) dusk anomalies. Shade interval 2 nT.

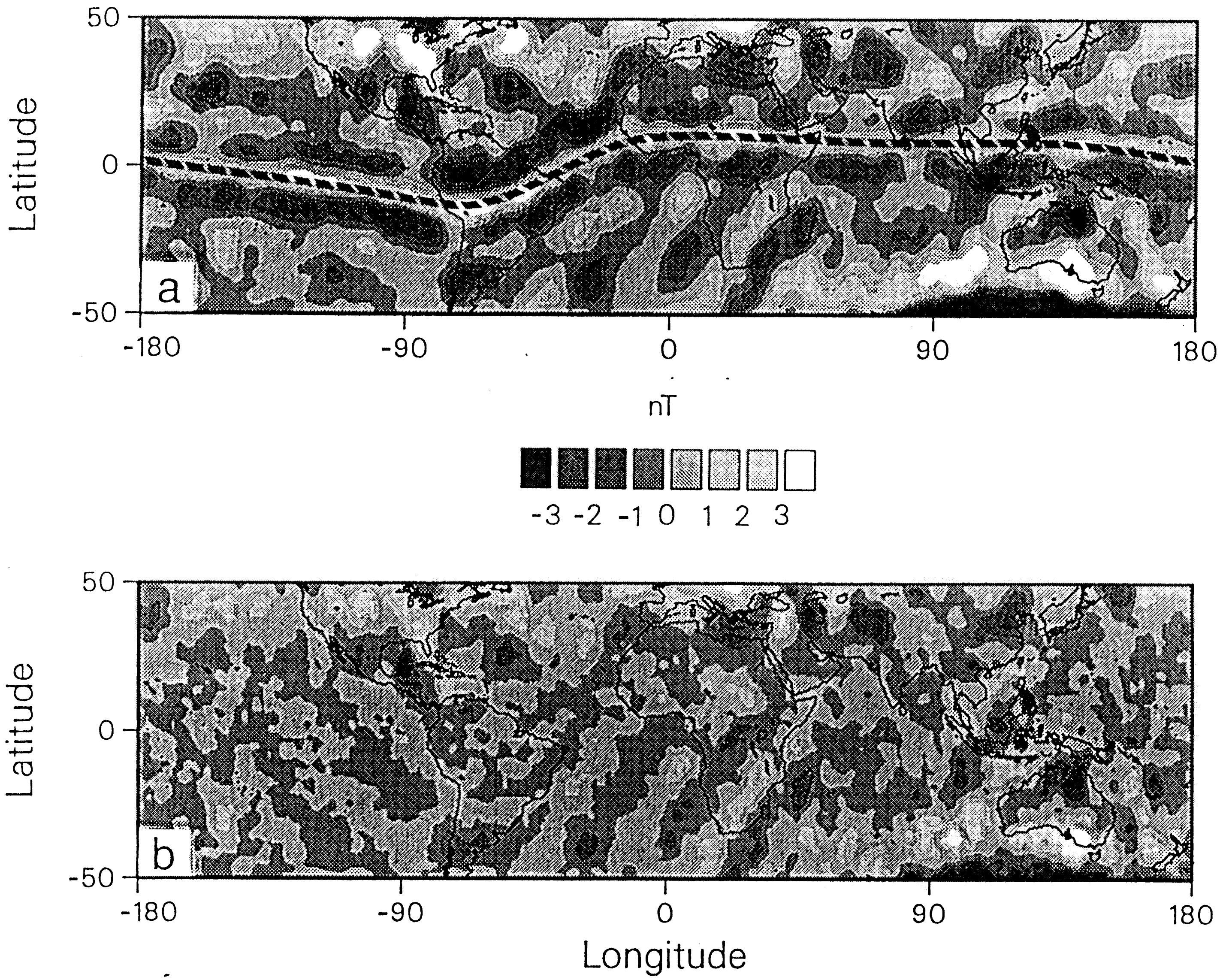

Figure 8. Dawn-dusk anomaly discrepancies a) before and b) after the improved corrections implemented in this study. Shade interval 1 nT. The heavy dashed line is the position of the dip equator. No dip latitude oriented trends are present in the equatorial portion of the improved discrepancy map.

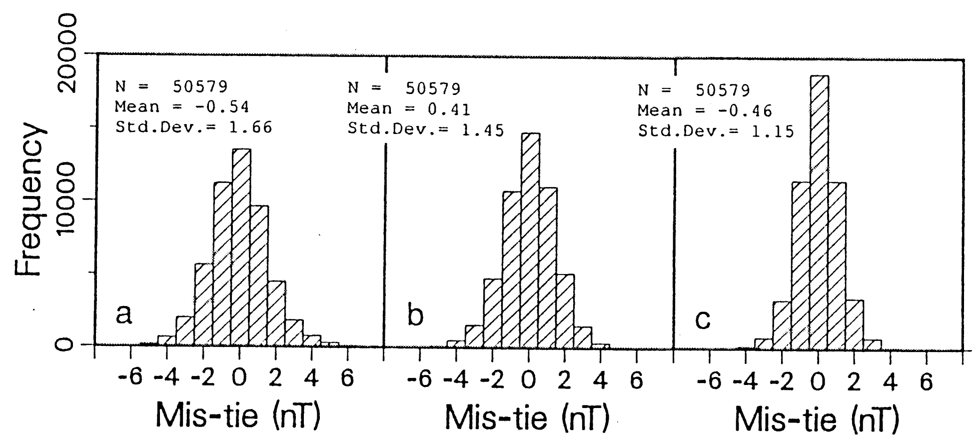

Figure 9. Histograms of dawn-dusk discrepancies a) before any ionospheric correction, b) after simple average-altitude ATDL correction, and c) after improved scaled ATDL correction. Shrinking standard deviations suggest that significant improvements in the statistical parameters of the dawn-dusk discrepancies are observed as a result of the ATDL corrections.

(A)

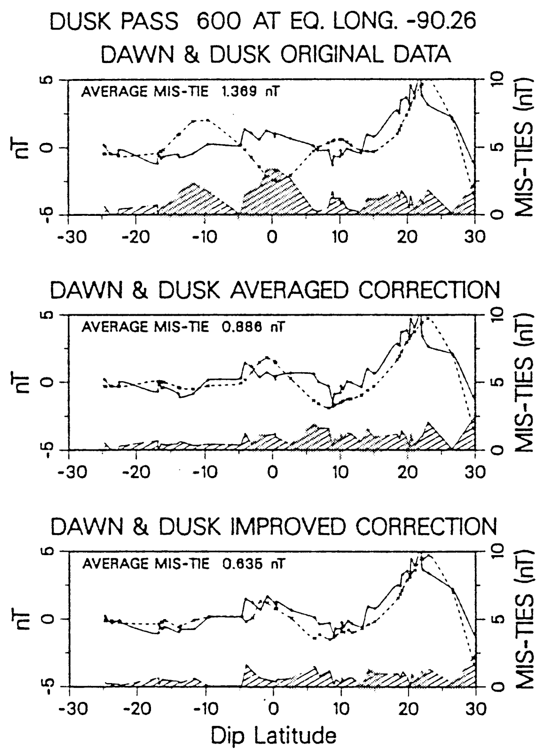

Figure 10. Data along three dawn and dusk profiles that show various examples of success and failure of the correction procedures. Dawn- continuous line, dusk- dashed line. Interpolated data points at the cross-over locations are shown by + for dawn and by x for dusk. The magnitude of mis-ties are shown by shaded areas at the bottom of each panel. The top panel represents the original data, the middle panel represents the data after simple average-altitude correction, and the bottom panel represents the data after the improved scaled ATDL correction. See text for percentages of various types.

(B)

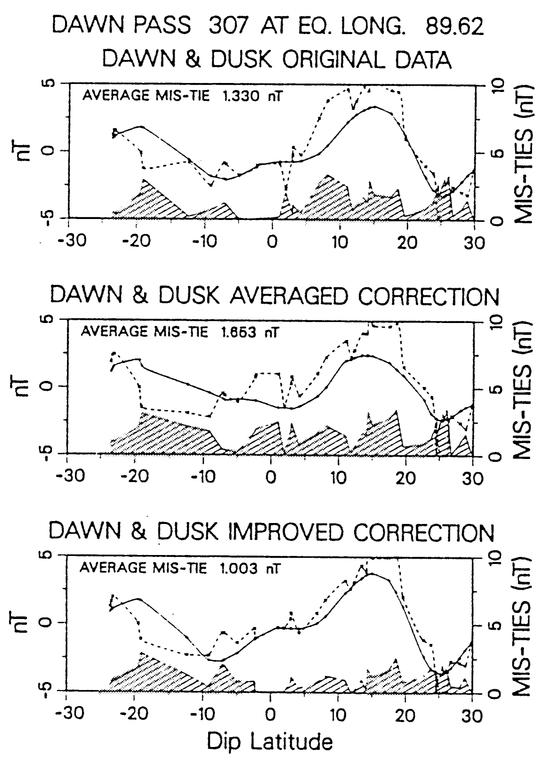

Figure 10 (cont.)

(C)

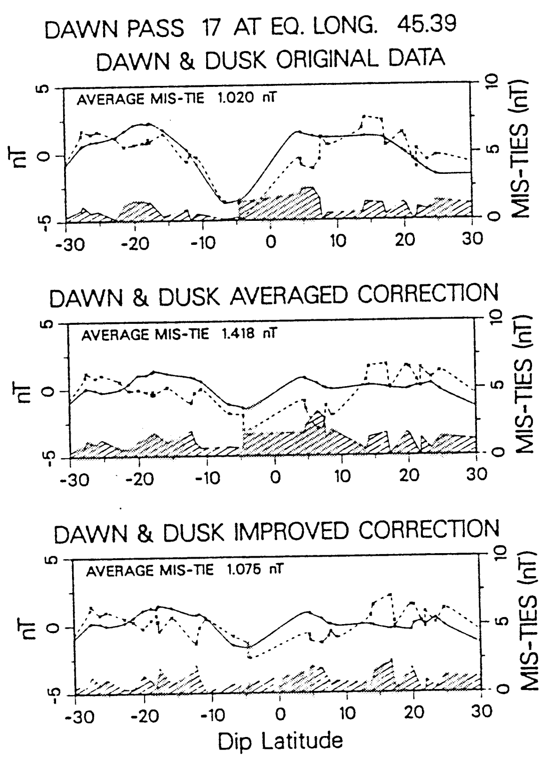

Figure 10 (cont.)

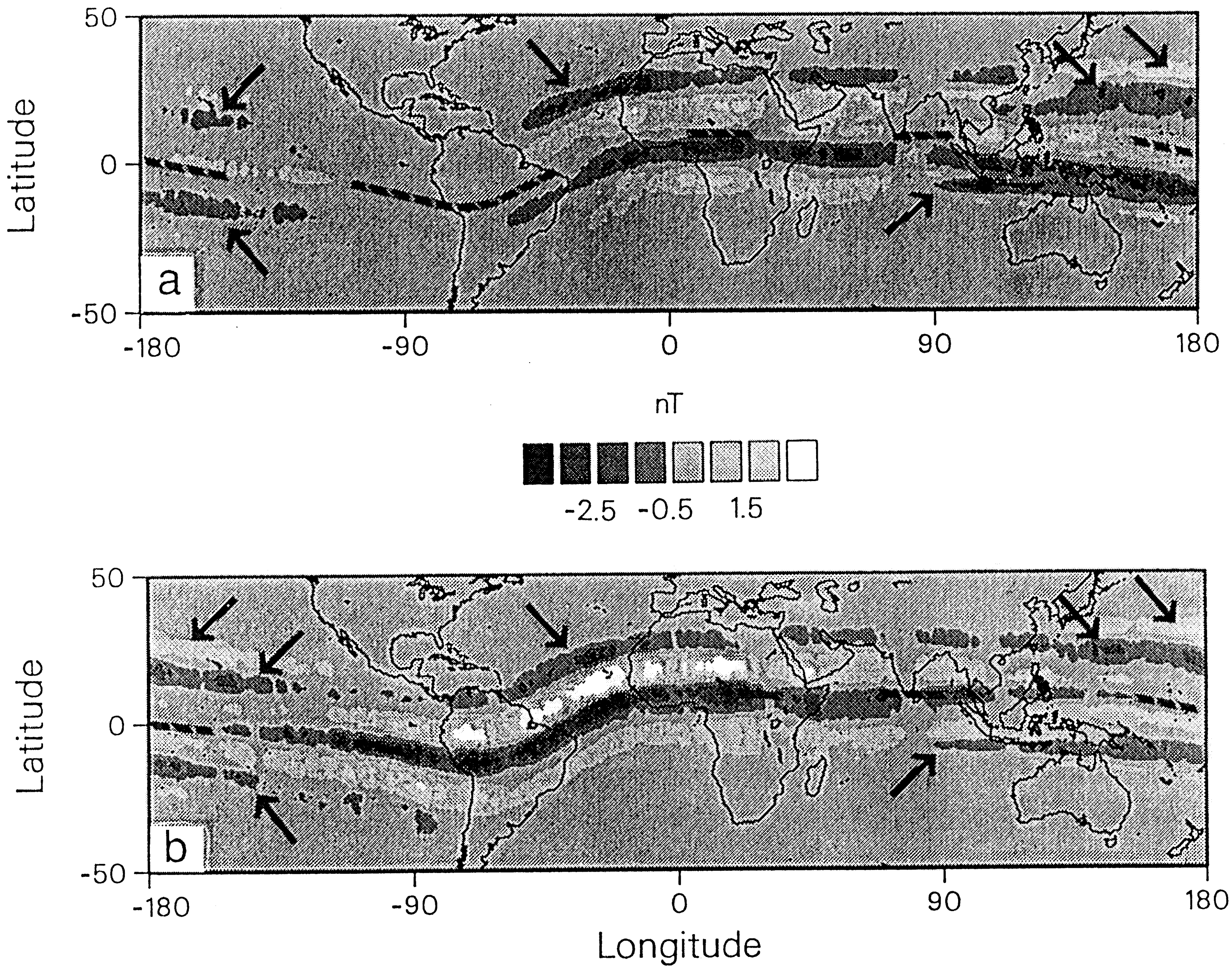

Figure 11. Snap-shots of the equatorial ionospheric effect at 400 km altitude based on the improved corrections utilized in this study; a) at 0600 hours local time and b) at 1800 hours local time. Arrows point to anomaly trends that are suspected to be of lithospheric origin in part.

APPENDIX B

Citation #1

Ravat, D.N., and W.J. Hinze, 1991, Considerations of variations in ionospheric field effects in mapping equatorial lithospheric MAGSAT magnetic anomalies, J. Geophysics (to be submitted).

Considerations of Variations in Ionospheric Field Effects in Mapping Equatorial Lithospheric MAGSAT Magnetic Anomalies

D.N. Ravat[1] and W.J. Hinze[2]

Abstract

For improved isolation of equatorial lithospheric MAGSAT magnetic anomalies, longitudinal, seasonal, and altitude-dependent variability of "ionospheric" averages is investigated. An estimate of the "ionospheric effect" was compiled by averaging the total intensity MAGSAT anomalies as a function of dip latitudes (called 'along-the-dip-latitude' or ATDL averages) from the dawn and the dusk data sets grouped according to longitudes, time (months), and altitudes. Consideration of longitudinal and altitude-dependent variations in the ATDL averages is important to the isolation of the equatorial lithospheric MAGSAT anomalies. Small, but unanticipated seasonal variations were found in the dusk MAGSAT data over the African-Indian sector; if the observed seasonal variations are real, they would significantly contribute toward the theoretical understanding of the equatorial electrojet.

The amplitudes of the dawn ATDL averages are small in comparison to the dusk averages and they are of opposite sign as anticipated from the westward and eastward flowing currents at the dip equator at dawn and dusk time, respectively. However, longitudinal variation in the equatorial amplitudes of the dawn ATDL averages is not entirely consistent with present knowledge of the electrojet field. In the past, dawn MAGSAT anomalies have been considered to be free of the ionospheric fields. However, in the preparation of the lithospheric component maps, neglecting to remove the dawn ATDL averages from the dawn MAGSAT data set leaves conspicuous east-west trending anomalies in certain regions of the world. Removal of both the dawn and the dusk ATDL averages from their respective data sets substantially improves the agreement between the separately prepared dawn and dusk lithospheric component MAGSAT maps. Despite the agreement between the resultant lithospheric anomaly maps, ATDL averages do appear to contain some contribution from the lithospheric fields. Thus, processing of the data with the aid of the ATDL averages unavoidably removes a small degree of east-west oriented lithospheric signal as well.

[1]Department of Geology, Southern Illinois University, Carbondale, IL 62901

[2]Department of Earth and Atmospheric Sciences, Purdue University, West Lafayette, IN 47907

Citation #2

Ravat, D.N., 1989, MAGSAT investigations over the greater African region, Unpubl. Ph.D. Dissertation, Purdue University, 234 pp.

MAGSAT Investigations Over the Greater African Region

D.N. Ravat

Abstract

A high-resolution wide-band MAGSAT total intensity magnetic anomaly map of the greater African region has been prepared that is useful for constraining regional geologic and tectonic interpretations. Magnetic anomaly discrepancies in the MAGSAT dawn and dusk orbital cross-overs (mis-ties) are used to establish improved data selection criteria and problem-oriented data processing techniques. Empirical and random data handling techniques have been developed to minimize both the spatially coherent and random errors in the data. The processing has yielded wide-band dawn and dusk orbital MAGSAT data sets of the greater African region which have substantially reduced dawn-dusk discrepancies compared to other published wide-band maps. High correlation between the two data sets suggests that they are internally consistent, relatively free from external field effects, and hence, useful for broad-scale lithospheric magnetic anomaly interpretation.

The ridge-regression method has been used in a large-scale equivalent source inversion of MAGSAT data. The optimum damping parameter is selected based on the rate of increase of the variance in the residual between the observed and the calculated anomaly and the variance of the solution for a series of damping parameters. Solutions obtained by the damping parameter selected in this manner are numerically stable and geologically meaningful. Consequently, these solutions can be used in various applications such as transformation into effective magnetic susceptibility variation and differential reduction-to-pole.

There is a high degree of correspondence between MAGSAT anomalies and regional Euro-African geotectonic provinces. Moreover, the visually inferred differences in magnetic contrasts between shields and basins, shields and Phanerozoic foldbelts, and oceanic uplifts and the remaining ocean floor have been found to be statistically significant. Comparison of the high-resolution Afro-South American radially-polarized MAGSAT anomalies suggests that the Pangea reconstruction is a useful regional satellite magnetic anomaly verification tool. Furthermore, the consistency of MAGSAT magnetic contrasts and the geologic processes on the conjugate plates provide significant constraints for the geologic interpretation of the anomalies. In addition, three-dimensional quantitative magnetic models constrained by available geologic and geophysical data have been generated for West Africa, Central Africa, Southern Africa, Europe, and Northeastern Walvis Ridge that demonstrate the utility of the MAGSAT maps in regional geotectonic studies.

Dept. of Geology, Southern Illinois University, Carbondale, IL 62901

Citation #3

Ravat, D.N., W.J. Hinze, and R.R.B. von Frese, 1991, Analysis of MAGSAT magnetic contrasts across Africa and South America, Tectonophysics (in press).

Analysis of MAGSAT Magnetic Contrasts Across Africa and South America

D.N. Ravat[1], W.J. Hinze[2], and R.R.B. von Frese[3]

Abstract

Comparisons of MAGSAT magnetic contrasts and geology across the Mesozoic assembly of Africa and South America provide new insight into the interpretation of the long-wavelength magnetic anomalies near the present continental margins. Across continental Africa and South America, the MAGSAT magnetic contrasts can be correlated with geologic provinces formed before the Mesozoic separation of the continents. On the continents, areas affected by significant Mesozoic hotspot tectonism display negative magnetic contrasts suggesting a causative relationship between hotspot tectonism and the origin of the observed magnetic contrasts. The magnetic characteristics of a portion of the lower crust in these areas appear to have been significantly altered during the Mesozoic hotspot epeirogeny. By analogy with the processes of continental rifting, it is suggested that the magnetic mineralogy of the intruded lower crust may be dominated by weakly-to-non-magnetic titanomagnetites.

Oceanic magnetic contrast comparisons show that the positions of magnetic anomaly highs over the Rio Grande-Walvis Ridge System of the South Atlantic are consistent with the interpretation of their evolution over the Walvis Hotspot. However, only the parts of these ridges that were formed during the Cretaceous normal polarity geomagnetic epoch bear strong magnetic contrasts. Remanent magnetization thus appears to be an important contributor toward the MAGSAT magnetic anomalies of these features.

[1]Department of Geology, Southern Illinois University, Carbondale, IL 62901

[2]Department of Earth and Atmospheric Sciences, Purdue University, West Lafayette, IN 47907

[3]Department of Geology and Mineralogy, The Ohio State University, Columbus, OH 43210

Citation #4

Ravat, D.N., and W.J. Hinze, 1990, Variations in equatorial ionospheric effects: Their impact on mapping long-wavelength lithospheric magnetic anomalies, EOS, 71, p. 485.

Variations in Equatorial Ionospheric Effects: Their Impact on Mapping Long-Wavelength Lithospheric Magnetic Anomalies

D.N. Ravat[1] and W.J. Hinze[2]

Abstract

Significant temporal and spatial variations in equatorial ionospheric effects have controlled the utility of lithospheric MAGSAT anomaly maps. Time-dependent latitudinal variations are observed in the ionospheric component from equatorial MAGSAT data. The variability appears to be related to the morphology of the equatorial S_q or S_D fields. Both dawn and dusk equatorial MAGSAT subsets contain these ionospheric effects.

Comparison of African and South American MAGSAT data suggests that significant longitudinal amplitude variations are also present in equatorial regions. Ionospheric signatures in MAGSAT data are compatible with day-time POGO and ground observatory data. However, there are significant amplitude differences in the longitudinal variations between the dawn and dusk MAGSAT subsets. The longitudinal amplitude variations cause imprecise approximation of ionospheric effects by global along-the-dip-latitude averaging. Present averaging schemes based on segments of the globe are useful in minimizing the ionospheric effects and reduce the MAGSAT dawn-dusk discrepancies or "noise" to a level comparable to mid-latitude MAGSAT observations. Despite the utility of the present reduction techniques, improvements that take into account temporal and spatial variability are important for precise mapping of lithospheric magnetic anomalies.

[1]Department of Geology, Southern Illinois University, Carbondale, IL 62901

[2]Department of Earth and Atmospheric Sciences, Purdue University, West Lafayette, IN 47907

Citation #5

Hinze, W.J., and P.T. Taylor, 1991, Regional magnetic anomalies for crustal studies: Opportunities and challenges, XXth General Assembly IUGG, Vienna, Austria, 11-24 August 1991, IAGA Program and Abstracts, p. 641.

Regional Magnetic Anomalies for Crustal Studies: Opportunities and Challenges

W.J. Hinze[1] and P.T. Taylor[2]

Αβστραχτ

Over the past decade, regional magnetic anomalies have taken on an increasingly important role in synergistically investigating the earth's crust with related geophysical and geologic data. These magnetic anomalies are associated not only with structural and igneous intrusive perturbations of the crust, but with variations in rock chemistry, thermal history and related geochemical processes that are important in studying the nature and dynamics of the crust. Increasing interest in regional magnetic anomalies has developed as a result of numerous technological advances that have made these data more precise and readily available over extensive regions of the earth. Long-wavelength anomalies obtained from compilations of near-surface surveys and satellite-derived data anomalies highlight different geologic features and, thus, both should be considered in regional crustal studies. The relative attributes of these data sets are well illustrated in the midcontinent data sets of North America. The near-surface data show the effect of problems in compositing multiple data sources and variations in survey specifications. In contrast, satellite-altitude data: (1) lack horizontal/vertical resolution, (2) consistent coverage, and (3) are significantly affected by external variations. In addition, several interpretational difficulties remain in the North American data set. For example, the Proterozoic Midcontinent Rift System, with its basins filled with intensely magnetized basalts and late stage clastic sedimentary rocks, is generally mapped as a high-amplitude positive gravity anomaly, while several segments of the rift have no magnetic anomalies. Thus, numerous challenges exist in improving both near-surface and satellite-elevation data sets and their interpretation. Our responses to these challenges will open up significant opportunities for an expanding role for regional magnetic anomalies in crustal studies.

[1]Department of Geology, Southern Illinois University, Carbondale, IL 62901

[2]Goddard Space Flight Center, Code 922, NASA, Greenbelt, MD 20771

Citation #6

Taylor, P.T., W.J. Hinze, and D.N. Ravat, 1991, The search for crustal resources: MAGSAT and beyond, Adv. Space Res., in press.

The Search for Crustal Resources: MAGSAT and Beyond

P.T. Taylor[1], W.J. Hinze[2], and D.N. Ravat[3]

Abstract

In the decade since global satellite magnetic field data have been available from MAGSAT, notable progress has been made in processing these data for purposes of mapping crustal anomalies. Several regional magnetic anomaly maps compiled using these new techniques (e.g. Kursk region, U.S.S.R.; central Africa; Kiruna, Sweden; and the U.S.A. midcontinent) provide insight into the nature and tectonic evolution of the crust that contribute to conceptual crustal models useful in regional resource exploration. A recent mail survey of geopotential-field specialists involved in resource exploration indicates interest in MAGSAT data and future satellite missions with improved resolution. It is apparent that magnetic anomalies derived from satellite observations can aid in the search for crustal resources.

[1]Goddard Space Flight Center, Code 922, NASA, Greenbelt, MD 20771

[2]Department of Geology, Southern Illinois University, Carbondale, IL 62901

[3]Department of Geology, Southern Illinois University, Carbondale, IL 62901